This document includes Section 6.0, DD 963 Class: Vessels with Conventional Steam–propulsion, of the Draft EPA Report "Surface Vessel Bilgewater/Oil Water Separator Feasibility Impact Analysis Report" published in 2003. The reference number is: EPA-842-D-06-019

DRAFT
Feasibility Impact Analysis Report Surface Vessel Bilgewater/Oil Water Separator

Section 6.0 – DD 963 Class: Vessels with Conventional Steam–propulsion

2003

SECTION 6.0 – DD 963 CLASS

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6.0 DD 963 CLASS

The USS SPRUANCE Class (DD 963) was selected to represent the group of vessels that rely on gas turbines for main propulsion and have a wet bilge design. These vessels are similar to the DDG 51 Class, however, their designs differ in the way that bilgewater is collected. There are 22 vessels within the DD 963 vessel class. DD 963 Class vessels spend 182 days within 12 nautical miles (nm) of shore, where 178 days are spent pierside, and 4 cumulative days are spent in transit annually (Navy and EPA, 2003). DD 963 Class vessels annually operate 183 days beyond 12 nm of shore (Navy and EPA, 2003). The total volume of bilgewater generated within 12 nm is calculated by adding the volume of bilgewater generated in port to the volume generated while operating within 12 nm (e.g., steaming within 12 nm that occurs while transiting out to 12 nm). The in-port bilgewater generation rate assumed to be is 2,500 gallons per day (gpd), and the underway (both transiting and beyond 12nm) rate is assumed to be 10,000 gpd (Navy and EPA, 2003). Each DD 963 Class vessel generates approximately 485,000 gallons of bilgewater within 12 nm and 1,830,000 gallons of bilgewater beyond 12 nm annually.

Bilgewater generated within 12 nm:

$$\frac{178\text{ days (pierside)}}{\text{yr}} \bullet \frac{2{,}500\text{ gal}}{\text{day}} + \frac{4\text{ days (underway)}}{\text{yr}} \bullet \frac{10{,}000\text{ gal}}{\text{day}} = 485{,}000\ \text{ gal/yr}$$

Bilgewater generated beyond 12 nm:

$$\frac{183\text{ days (underway)}}{\text{yr}} \bullet \frac{10{,}000\text{ gal}}{\text{day}} = 1{,}830{,}000\ \text{ gal/yr}$$

DD 963 Class vessels use a 10 gallons per minute (gpm) gravity coalescence type oil water separator (OWS) (Navy model OPB-10NP) to process bilgewater. Consequently, this option is referred to as the current marine pollution control device (MPCD). DD 963 Class vessels use one 90-gpm pump to transfer oily waste and waste oil to shore collection facilities.

Where appropriate, the current MPCD was used to determine the operational capacities and other parameters used to evaluate each of the MPCDs in the feasibility analysis. The following MPCDs are evaluated for DD 963 Class vessels: gravity coalescence; centrifuge; collection, holding and transfer (CHT); evaporation; hydrocyclone; *in situ* biological treatment; oil absorbing socks; filter media; and membrane filtration.

6.1 GRAVITY COALESCENCE

The following sections discuss the feasibility and cost impacts of installing and operating gravity coalescence units on-board DD 963 Class vessels.

6.1.1 Practicability and Operational Impact Analysis

This section describes the analyses of specific feasibility criteria relative to the physical characteristics and operational requirements of gravity coalescence units.

6.1.1.1 Space and Weight

As described in Section 6.0, the analysis of gravity coalescence will include one 10-gpm gravity coalescence unit (OPB-10NP) and one 90-gpm pump. The gravity coalescence OWS on-board these vessels is intended for single-deck operation and is commonly installed in the main or auxiliary machinery spaces, in the vicinity of the oily waste holding tank (OWHT). Table 6-1 provides the space and weight specifications for the OPB-10NP.

Table 6-1. OPB-10NP Specifications (DD 963 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	6 x 2.5 x 4.2	10 x 4.5 x 6.2	63	1250/2710
Total (To achieve required processing capacity)	1	10 gpm	-	-	63	1250/2710

Clearance is required above the OWS tank assembly to mount chain falls for removal of the tank cover.

6.1.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with gravity coalescence units. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials required for operation and maintenance (e.g., oil and grease) are minimal in quantity and authorized for use on board vessels of the Armed Forces. Standard afloat control and management procedures are adequate for use and disposal of the material. While gravity coalescence units require electrical power, existing standard shipboard safety procedures for handling electrical equipment are adequate to protect personnel safety.

6.1.1.3 Mission Capabilities

The use of the OPB-10NP unit on DD 963 Class vessels has not resulted in any impact on ship's signature, war-fighting capabilities, mobility, or on any mission critical systems or operations.

6.1.1.4 Personnel Impact

The OPB-10NP separator runs in automatic mode, but requires general supervision while the unit is operating. Based on an MPCD rated capacity of 10 gpm, and the annual bilgewater generation within 12 nm of shore of 485,000 gallons, the number of hours the gravity coalescer is operated annually within 12 nm is 810 hours.

$$\frac{485{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 810\text{ hrs/yr}$$

Based on operational experience, the time required per year to supervise the operation of the OPB-10NP separator is 0.25 hours (15 minutes) for every two hours that the unit operates. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Based on the annual operating requirement of 810 hours, the annual labor requirement associated with the operation of a gravity coalescence unit within 12 nm of shore is 100 hours, as calculated below:

$$\frac{810 \text{ hrs operation}}{\text{yr}} \bullet \frac{0.25 \text{ hrs labor}}{2 \text{ hrs operation}} = 100 \text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event. One crewmember is required to operate the waste oil transfer pump and associated valves/hull connections. A second crewmember is required to oversee the connections of transfer hoses for the offloading vessel. A third crewmember oversees the connection of transfer hoses for the receiving vessel or facility. The two crewmembers overseeing the transfer stand near the hose connections in case the connections separate. The two crewmembers also ensure that appropriate precautions are taken to prevent oil spills. During waste oil transfer activities, two-way voice communication must be established between the three crewmembers overseeing the oil transfer (Navy, 2002). The labor hours associated with transferring the waste oil produced by a gravity coalescence unit on a DD 963 Class vessel within 12 nm of shore are calculated by dividing the waste oil volume (1 percent of the bilgewater volume generated within 12 nm of shore, i.e., 4,850 gal of waste oil) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}850 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 2.7 \text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of the gravity coalescence unit within 12 nm and transfer of waste oil generated within 12 nm on a DD 963 Class vessel is 100 hours.

The total labor requirement associated with gravity coalescence operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The volume of bilgewater generated beyond 12 nm (i.e., 1,830,000 gal) and resultant volume of waste oil that requires offloading to shore (i.e. 18,300 gal) are based on the DD 963 Class vessel underway bilgewater generation rate of 10,000 gpd. The underway generation rate is multiplied by the number of days spent beyond 12 nm (183 days). Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}830{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 3{,}100\text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{3{,}100\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hrs labor}}{2\text{ hrs}} = 380\text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{18{,}300\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 10\text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of this vessel class beyond 12 nm is 390 hrs/yr.

Annually, the OPB-10NP requires approximately 4.1 personnel hours of time-based maintenance, 18 personnel hours of conditioned based maintenance within 12 nm, and 66 personnel hours of condition-based maintenance beyond 12 nm Table 6-2 and Table 6-3 summarize the time-based and the condition-based maintenance requirements, respectively, for one OPB-10NP separator.

Table 6-2. OPB-10NP Time-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Lubricate Pump Packing	0.1	6 months	0.2
Inspect Air Vent Valve	1	6 months	2
Clean and Inspect Flow Totalizer	1	12 months	1
Inspect OWS Pump Assembly Drive Belt	0.2	12 months	0.2
Lubricate OWS Pump Motor Bearings	0.5	12 months	0.5
Test Operation of OWS Pump Relief Valve	0.3	18 months	0.2
Total Annualized Hours	-	-	4.1

Table 6-3. OPB-10NP Condition-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 810 operation hours within 12 nm)	Annualized Maintenance Hours (based on 3,100 operation hours beyond 12 nm)
Clean and Inspect Check Valves	0.5	1000	0.4	1.5
Clean and Inspect Separator Level Sensor Probes	0.8	1500	0.4	1.6
Clean and Inspect Coalescing Plates and Separator Tank	16	1000	13	49
Lubricate OWS Pump Bearings	7	1500	3.8	14
Total Annualized Hours	-	-	18	66

Table 6-4 provides the annual labor hours required to operate and maintain the current MPCD, gravity coalescence.

Table 6-4. Gravity Coalescence Annual Labor Hours (DD 963 Class)

	MPCD Option: Gravity Coalescence (Current MPCD)
Operator Hours Within 12 nm	100
Operator Hours Beyond 12 nm	390
Condition-based Maintenance Within 12 nm	18
Condition-based Maintenance Beyond 12 nm	66
Time-based Maintenance	4.1
Total Time	580

6.1.1.5 Consumables, Repair Parts, and Tools

Gravity coalescence units installed on DD 963 Class vessels do not require consumables. No special tools are required for the operation or maintenance of these units.

6.1.1.6 Interface Requirements

Table 6-5 summarizes specific system interface requirements associated with the OPB-10NP OWS.

Table 6-5. OPB-10NP Interface Requirements (DD 963 Class)

Shipboard System	OPB-10NP Interface Requirements
Electrical Power	440V/3PH/60Hz
Potable Water	May be used for priming
Seawater	Minimal pressure required for priming
Drainage	Gravity drain to bilge or OWHT

6.1.1.7 Control System Requirements

The gravity coalescence units installed on-board DD 963 Class vessels are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. One level switch will start the unit when the liquid level in the tank reaches a pre-set level. When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit to shut down. Units have a flow sensor that will secure the system if the pump loses suction and a remote alarm/indicator panel, which allows shipboard personnel to monitor the operating status of the units while in the automatic mode of operation. The remote alarm/indicator contains visual indicators that allow operating personnel to monitor the overall status of the system and an audible alarm that warns of system malfunction.

In addition, OPB-10NP units are equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be retreated by the OWS.

6.1.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

6.1.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a gravity coalescence system on a DD 963 Class vessel.

6.1.2.1 Initial Cost

There are no initial costs associated with gravity coalescence on a DD 963 Class vessel because the equipment is in place as described above.

6.1.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 130 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm, as explained under Section 6.1.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the annual recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{130\ \text{hrs}}{\text{yr}} = \$2{,}800/\text{yr inside } 12\ \text{nm}$$

Personnel Labor Beyond 12 nm

This MPCD requires 460 personnel hours per year for operation and condition-based maintenance within 12 nm, as explained under Section 6.1.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{460\ \text{hrs}}{\text{yr}} = \$10{,}000/\text{yr outside } 12\ \text{nm}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 6-6 provides the annual recurring costs for a gravity coalescer system on a DD 963 Class vessel.

Table 6-6. Annual Recurring Costs for Gravity Coalescence (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	2.8
Beyond 12 nm	Navy	10.0

6.1.2.3 Total Ownership Cost (TOC)

Table 6-7 summarizes the TOC and annualized cost over a 15-year lifecycle of a gravity coalescer system on a DD 963 Class vessel.

Table 6-7. TOC for Gravity Coalescence (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0.00	0.00
Total Recurring	32	150
TOC (15-yr lifecycle)	31	150
Annualized	2.7	13

6.2 CENTRIFUGE

The following sections discuss the feasibility and cost impacts of installing and operating centrifuges on-board DD 963 Class vessels.

6.2.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of centrifuges.

6.2.1.1 Space and Weight

DD 963 Class vessels are equipped with one 10-gpm gravity coalescing type OWS. One 15-gpm centrifuge unit (Westfalia model WSC 15) is proposed in this analysis. This unit was chosen because it has a rated capacity similar to the current MPCD in place on DD 963 Class vessels. Additionally, the unit is manufactured by a major supplier of centrifuges used in the marine industry and is representative in space, weight, and power requirements of centrifuges with a similar processing capacity. Table 6-8 provides the space and weight specifications for the centrifuge, which comes as a complete 15-gpm module (includes centrifuge and heater) unit.

Table 6-8. WSC 15 Specifications (DD 963 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	15 gpm	4 x 5.25 x 6.5	5 x 6.5 x 7.3	136.5	2650/2700
Total (To achieve required processing capacity)	1	15 gpm	-	-	136.5	2650/2700

The centrifuge is designed for single deck operation and would be installed in the existing OWS room. The existing OWS would be removed and replaced with the centrifuge unit.

6.2.1.2 Personnel/Equipment Safety

Integral heaters provided as part of the centrifuge module preheat the bilgewater to 90 - 95^{o}C. However, the heater and associated piping are well insulated and should not pose a burn hazard to personnel. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials required for operation and maintenance (e.g., oil and grease) are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While centrifuges require electrical power, observing standard shipboard safety procedures for handling electrical equipment should be adequate to protect personnel safety.

6.2.1.3 Mission Capabilities

The installation and operation of centrifuges on DD 963 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

6.2.1.4 Personnel Impact

The WSC 15 centrifuge runs in automatic mode, but requires general supervision while the unit is operating. Based on an MPCD rated capacity of 15 gpm and the 485,000 gallons of bilgewater generated annually within 12 nm, the number of hours the centrifuge would be operated annually within 12 nm is 540 hours.

$$\frac{485{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{15\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 540\text{ hrs/yr}$$

The labor requirement for general oversight of the centrifuge system is calculated as 0.25 hours for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, the annual labor requirement associated with the operation of a centrifuge within 12 nm is 67 hours.

$$\frac{540\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hr labor}}{2\text{ hrs operation}} = 67\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 6.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm of shore is calculated by dividing the waste oil volume (1 percent of the annual volume of bilgewater volume generated while operating within 12 nm of shore) by waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}850\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 2.7\text{ hr labor/yr}$$

The combined annual labor associated with the operational oversight of the centrifuge unit within 12 nm and transfer of waste oil generated within 12 nm on a DD 963 Class vessel is 70 hours.

The total labor requirement associated with vessel operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}830{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{15 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 2{,}000 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2{,}000 \text{ hrs}}{\text{yr}} \bullet \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 250 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{18{,}300 \text{ hrs}}{\text{yr}} \bullet \frac{\text{min}}{90 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 10 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of a WSC 15 centrifuge on DD 963 Class vessels beyond 12 nm is 260 hrs/yr.

Annually, the WSC 15 centrifuge requires approximately 20.75 personnel hours of time-based maintenance, 0 hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 6-9 and Table 6-10 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one WSC 15 centrifuge.

Table 6-9. WSC 15 Time-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Change Gear Case Oil	1	6 months	2
Remove, Clean, and Grease Bowl Lock Ring	1	6 months	2
Grease Motor Bearings	0.25	As needed*	0.25
Inspect and Clean Bowl	2	3 months	8
Check Starting Time. Check Thickness of Clutch Shoe Linings. Replace as Necessary.	0.25	6 months	0.5
Check Thickness of Brake Lining. Replace as Necessary	0.5	12 months	0.5
Check foundation bolts for proper tensioning. Check all readily accessible equipment bolts and fasteners for proper tension.	0.5	12 months	0.5
Check shock mounts for cracks, peeling of rubber, or any distortions. Replace as necessary.	0.25	12 months	0.25
Check to ensure that a clearance of 3 mm between the decelerator unit and ship's foundation is correct.	0.25	12 months	0.25
Replace Ball bearings on spindle	1	12 months	1

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Replace Ball bearings on worm wheel shaft	1	6 months	2
Check pump strainer. Clean as required.	0.25	6 months	0.5
Check water strainer(s). Clean as required.	0.25	6 months	0.5
Check to make sure operating water feeding device is not plugged.	0.25	6 months	0.5
Check and tighten system hardware including all foundations	1	12 months	1
Check motor winding resistance.	0.5	12 months	0.5
Check operation of pressure switch. Repair or replace as required.	0.25	6 months	0.5
Total Annualized Hours	-	-	20.75

**For calculations it was assumed that the time-based maintenance was performed annually.*

Table 6-10. WSC 15 Condition-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on operation hours within 12 nm)	Annualized Maintenance Hours (based on operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	-	0

Centrifuges are equipped with programmable logic controls and monitoring systems. The oil content monitor alarm can be monitored remotely or locally.

Operator certification is not required. Inexperienced equipment operators require four to six hours of training. Properly operating centrifuges pose no impact on habitability.

Table 6-11 summarizes the annual labor hours required for operation and maintenance of the WSC 15 centrifuge.

Table 6-11. Centrifuge Annual Labor Hours (DD 963 Class)

	MPCD Option: Centrifuge (WSC 15)
Operator Hours Within 12 nm	70
Operator Hours Beyond 12 nm	260
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	20.75
Total Time	360

6.2.1.5 Consumables, Repair Parts, and Tools

Centrifuges require consumables, repair parts, and special tools. In addition, a spare parts kit is available from the vendor. Consumables and repair parts include items such as filters, gaskets, "O" rings, and bearings. The special tools required are delivered with the machine and consist of spanner wrenches made specifically for dismantling the purifier bowl.

6.2.1.6 Interface Requirements

Table 6-12 lists the interfaces required to support one WSC 15 centrifuge module.

Table 6-12. WSC 15 Interface Requirements (DD 963 Class)

Shipboard System	WSC 15 gpm
Electrical Power	440VAC/3PH, 60-100kW (80-130 hp)
Compressed Air	0.0058 - 0.029 scfm @ 50 psig
Potable Water	20 gpd, 45 psi
Seawater	Requires 25 psi seawater pressure
Drainage	Gravity drain to OWHT

DD 963 Class vessels are able to accommodate these interface requirements with no significant impact on existing systems.

6.2.1.7 Control System Requirements

The manufacturer recommends that the operator manually turn on the equipment. However, once the centrifuge has reached its operating speed, the WSC 15 does not require constant oversight. It is fully automatic and equipped with an integrated thermostat to control the heater.

A centrifuge may be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS.

6.2.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

6.2.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a centrifuge system on the DD 963 Class vessel.

6.2.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $138,000 (Donohue, 2000). Based on previous Alteration and Installation Team (AIT) ship checks, the Navy estimates that installation of the MPCD will cost $103,300 per vessel (Navy, 2000). To install the unit, the existing gravity coalescence unit must first be removed from the OWS room in order to make space available for the centrifuge system. The installation would require approximately four weeks to complete. Technical manuals cost approximately $85,000 ($3,867 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $30,910 ($1,405 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($424 per vessel) (Smith, 2001). The total initial cost of a centrifuge system on a DD 963 Class vessel is $247,000 per vessel.

6.2.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 91 personnel hours per year for operation and time-based maintenance within 12 nm, as explained under Section 6.2.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{91\,\text{hrs}}{\text{yr}} = \$2{,}100\ /\text{yr inside}\ 12\ \text{nm}$$

Personnel Labor Beyond 12 nm

This MPCD requires 260 personnel hours per year for operation beyond 12 nm, as explained under Section 6.2.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{260\,\text{hrs}}{\text{yr}} = \$6{,}000\ /\text{yr outside}\ 12\ \text{nm}$$

The labor required to transfer waste oil generated by the centrifuge system to a disposal facility is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal facility is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 6-13 provides the annual recurring costs for a centrifuge system on a DD 963 Class vessel.

Table 6-13. Annual Recurring Costs for Centrifuge (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	2.1
Beyond 12 nm	Navy	6.0

6.2.2.3 Total Ownership Cost (TOC)

Table 6-14 summarizes the TOC and annualized cost over a 15-year lifecycle of a centrifuge system on a DD 963 Class vessel.

Table 6-14. TOC for Centrifuge (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	247	247
Total Recurring	23	90
TOC (15-yr lifecycle)	270	337
Annualized	22.9	28.6

6.3 COLLECTION, HOLDING, AND TRANSFER (CHT)

The following sections discuss the feasibility and cost impacts of not discharging bilgewater from DD 963 Class vessels (treated or untreated) to the environment within 12 nm from shore. This no-discharge option is referred to as the practice of CHT of bilgewater within 12 nm. The bilgewater may be transferred to shore facilities (including tanks, barges, and trucks) in port, processed through an OWS beyond 12 nm, or discharged overboard in accordance with applicable regulations beyond 12 nm.

6.3.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of CHT.

6.3.1.1 Space and Weight

DD 963 Class vessels are equipped with a series of OWHTs that have a combined design capacity of approximately 2,500 gallons. The holding tanks are designed with capacity 5-10 percent in excess of the ship's requirements, to minimize the risk of overfilling the tanks, which would result in spillage. These tanks are designed to collect and hold oily waste (i.e., bilgewater) for processing by the vessel's 10-gpm OWS unit or for transfer to shore, as applicable. As such, DD 963 Class vessels are capable of practicing CHT up to the existing holding capacity without experiencing any impacts to space and weight. The potential for exceeding the vessel's existing space and weight capacities, as a result of practicing CHT, will depend upon the length of time spent within 12 nm from shore, and whether the port visited has the capability to offload wastewater.

During a typical five-year operating cycle, DD 963 Class vessels may visit many ports for varying lengths of time. The longest stays in port (i.e., 30 days or more) tend to be at the vessel’s homeport or at other major Naval ports where extensive shore services, including wastewater offloading, are available. During these visits, DD 963 Class vessels typically do not operate their OWS units, but instead transfer their bilgewater to shore facilities. However, to support their operational requirements, DD 963 Class vessels may occasionally visit smaller non-Navy ports where offloading services are not available. In this situation, a DD 963 Class vessel could be required to collect and hold all bilgewater generated until the ship is beyond 12 nm or again has access to necessary shoreside offloading facilities. The following paragraphs will evaluate two potential scenarios: (1) arriving at a port where wastewater offloading services are available, and (2) arriving at a port where such services are not available.

Ports with wastewater offloading services: DD 963 Class destroyers are homeported in Norfolk, VA, San Diego, CA, and Everette, WA. These are all major Navy ports with complete shore services, including wastewater offloading. Once a vessel has tied up pierside at one of these ports, bilgewater can be transferred to shore as needed, with no additional holding tank space being required. DD 963 Class vessels can also collect and hold bilgewater generated while transiting from 12 nm to port for transfer shoreside. Of the three Naval ports previously mentioned, the transit to Everette represents the most extreme case for time in transit between 12 nm and port, which can take up to six hours. While underway, DD 963 Class vessels generate approximately 10,000 gpd of bilgewater, or 400 gallons per hour. Using the generation rate of 400 gallons per hour over 6 hours, the maximum volume of bilgewater generated would be approximately 2,400 gallons. Transits to ports other than Everette, WA will take less time and result in lower volumes of bilgewater generation. Once in port, DD 963 class vessels can transfer their bilgewater to shore as needed. Because the 2,400 gallons of bilgewater collected during transit is slightly under the estimated holding capacity for DD 963 Class vessels, practicing CHT while transiting to or from a port where shore offloading services are available will have no space or weight impacts.

Ports without wastewater offloading services: If the vessel is visiting a port where offloading bilgewater is not possible, the ship could be required to hold all bilgewater during the entire time spent within 12 nm. A typical visit to a small port may last two to five days. Assuming a five-day port visit, a DD 963 Class vessel would generate approximately 12,500 gallons of bilgewater (based on in-port generation rate). Using a generation rate of 400 gallons per hour and a maximum total transit time of 6 hours (3 hours in each direction), the vessel would generate an additional 2,400 gallons of bilgewater while transiting to and from port. The total bilgewater generated within 12 nm from shore would be 15,000 gallons. This is six times the estimated holding capacity of 2,400 gallons, and would result in considerable space and weight impacts. Under this scenario, a DD 963 Class vessel would be limited to practicing CHT for less than a single day without exceeding its design holding capacity.

Practicing CHT within the existing holding capability will not result in any space and weight impacts. While the above analyses describe operating scenarios, there may be situations where practicing CHT may exceed the vessel's existing holding capacity. Extra tank capacity would be required to accommodate any additional volume of bilgewater collected. Because the space and weight allocations on DD 963 Class vessels are tightly controlled, there is generally very little available unassigned space to accommodate additional tank capacity. Therefore, the most likely strategy for increasing bilgewater holding capacity would be to convert other existing tanks to bilgewater holding tanks. However, converting existing tank space to hold bilgewater would likely result in adverse impacts to those systems or services which rely on the tanks that would be converted for holding oily waste.

6.3.1.2 Personnel/Equipment Safety

Practicing CHT within the vessel's existing holding capacity will not pose any safety hazards to the vessel’s crew or equipment.

6.3.1.3 Mission Capabilities

Practicing CHT within the vessel's existing holding capacity will not have an impact on ship's signature, war-fighting capabilities, mobility, or on any mission critical systems or operations.

The ship designers review the ship's requirements (e.g., vessel's range, the number of crew, etc.) to determine what tank capacities are needed to allow the ship to fulfill its mission. With the exception of approximately five percent excess capacity as a margin of safety, ship designers do not size a vessel's tank capacity beyond what is necessary to meet the ship's operational requirements. Practicing CHT in excess of the vessel's holding capability would likely require that additional tanks be built or tanks used for other purposes be converted to bilgewater holding tanks. Reducing the capacity of existing tanks such as aviation fuel (JP-5) tanks, potable water tanks, or sewage tanks, will reduce the ship's existing capability to support its mission.

6.3.1.4 Personnel Impact

Practicing CHT within the vessel's existing holding capacity will not result in any personnel impacts other than time required to oversee the transfer of bilgewater and oily waste to shore (see analysis below).

Practicing CHT as a primary control option does not require special training. Manning is required to oversee the transfer of bilgewater to a shore facility or receiving vessel (i.e., operate the oily waste transfer (OWT) pump and associated valves/hull connections). This transfer requires three crewmembers per event as described in Section 6.1.1.4.

The DD 963 Class vessel generates 485,000 gallons of bilgewater annually within 12 nm. The annual volume of bilgewater generated within 12 nm of shore divided by the OWT pump rate (90 gpm), multiplied by the number (three) of crewmembers required for oversight, equals the personnel hours required per year for CHT on a DD 963 Class vessel.

$$\frac{485{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 270\text{ hrs labor/yr}$$

Table 6-15 provides the annual labor hours required for CHT.

Table 6-15. CHT Annual Labor Hours (DD 963 Class)

	MPCD Option: CHT
Operator Hours Within 12 nm	270
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	270

6.3.1.5 Consumables, Repair Parts, and Tools

There are no requirements for consumables, repair parts, or tools associated with CHT.

6.3.1.6 Interface Requirements

Practicing CHT does not require any unique interface requirements. OWT pumps and associated valves, piping, and hull connections exist on this vessel class to support the current practice of shoreside disposal.

6.3.1.7 Control System Requirements

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (i.e., during shoreside transfers) (Navy, 2002).

6.3.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option group.

6.3.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with practicing CHT on a DD 963 Class vessel. CHT is generally not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12 nm only. Vessels in this class will continue to comply with appropriate regulations beyond 12 nm.

6.3.2.1 Initial Cost

As described in Section 6.3.1.3, the reallocation of tank space to increase bilgewater holding capacity on a DD 963 Class vessel would result in adverse impacts on mission capabilities and personnel. For the cost analysis, it was assumed that the current bilgewater holding capacity could not be increased. Therefore, the initial cost of acquisition and installation of additional equipment such as tanks and piping systems is assumed to be zero.

6.3.2.2 Recurring Cost

Practicing CHT requires 270 personnel hours per year for operation and transfer of oily waste to shore, as explained under Section 6.3.1.4. The annual labor hours multiplied by the \$22.64 per hour MPCD operator labor rate produces an annual labor cost of \$6,100.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{270\ \text{hrs}}{\text{yr}} = \$6{,}100/\text{yr}$$

The annual bilgewater generation rate within 12 nm is 485,000 gallons. The volume of bilgewater generated annually within 12 nm multiplied by the oily waste disposal unit cost results in an annual recurring disposal cost of \$36,300.

$$\frac{485{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.0749}{\text{gal}} = \$36{,}300 \text{ /yr}$$

Table 6-16 provides the annual recurring costs for practicing CHT on a DD 963 Class vessel.

Table 6-16. Annual Recurring Costs for CHT (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	42.4
Beyond 12 nm	Navy	-

6.3.2.3 Total Ownership Cost (TOC)

Table 6-17 summarizes the TOC and annualized cost over a 15-year lifecycle of practicing CHT on a DD 963 Class vessel.

Table 6-17. TOC for CHT (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0	0
Total Recurring	473	473
TOC (15-yr lifecycle)	473	473
Annualized	40.2	40.2

6.4 EVAPORATION

Commercial evaporation units are designed to operate with freshwater waste streams (Navy and EPA, 2000b). In order to apply evaporation technology in a saltwater environment, design concerns such as corrosivity, plating out of salt in the unit, and buildup of salt and sludge would need to be addressed before this technology was considered feasible on this vessel class. The following analysis is provided to further demonstrate the feasibility of this MPCD.

As discussed in Section 6.0, DD 963 Class vessels are equipped with one 10-gpm gravity coalescer OWS. Operating this MPCD in batch mode (i.e., operating at maximum capability to eliminate accumulating bilgewater) minimizes the impact on the vessel's crew A bilgewater evaporator with the maximum available processing rate, one gpm, was chosen for this analysis to minimize the number of units required. A total of 10 evaporation units, each requiring 162 kW of electrical power to operate, would be required to meet the current processing rate. DD 963 Class vessels have a total electrical capacity of 6000 kW and a designed operating capacity of 3,600 kW. The designed operating capacity is based on the assumption that one ship service generator is out of service and the remaining generators are operating at 90 percent capacity (Navy, 1980). The designed operating capacity includes a 20 percent service life margin (600 kW) to support the addition of electrical equipment throughout the vessel's lifecycle (Navy, 1980). The service life margin represents the total electrical capacity available to support additional electrical equipment that may be installed following initial construction. The use of evaporators would constitute a total electrical load of 1,620 kW, which is greater than the 600 kW service life margin available.

A significant amount of electrical power is required by Armed Forces vessels to support mission-related payloads such as the combat systems (e.g., weapons, command, communications, control, electronic warfare and countermeasures, etc.) and combat support and supply systems. Because the use of evaporators would exceed the vessel's service life margin, mission essential electrical equipment would have to be shut off while running the evaporators. This equipment is essential for vessel safety and defense. Not operating this equipment while running the evaporators would leave the vessel vulnerable to safety hazards (e.g., collisions) and potential military threats. Because the evaporators' power requirements could degrade the vessel's mission and safety capabilities, evaporation is not a feasible MPCD option group for DD 963 Class vessels.

An alternative to batch processing would be continuous processing where the number of evaporation units are selected such that their total rated processing rate is slightly in excess, ten to twenty percent, of the bilgewater generation rate. It is still expected that the number of units required to support this scenario would be prohibitive, due to the need to compensate for the unpredictable generation rate of bilgewater. Additionally, this scenario would require more crew oversight because operation of the units would be dependent upon the generation of bilgewater, which typically varies in volume over a period of time. The time required for oversight along with the time required to manually remove the accumulation of salt and sludge from inside the evaporators would hinder the crew's ability to perform mission related tasks thereby decreasing the vessel's operational flexibility.

6.5 HYDROCYCLONE

The following sections discuss the feasibility and cost impacts of installing and operating a hydrocyclone on-board a DD 963 Class vessel.

6.5.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of hydrocyclones.

6.5.1.1 Space and Weight

DD 963 Class vessels are equipped with one 10-gpm gravity coalescing type OWS. One 13-gpm hydrocyclone unit (Krebs model Spinifex 3000) is proposed in this analysis. This unit was chosen because it has a processing capacity similar to the current MPCD in place on DD 963 Class vessels and is representative in space, weight, and power requirements of hydrocyclones with similar processing capacities. Table 6-18 provides the space and weight specifications for a Spinifex 3000 Module (13 gpm) consisting of a strainer basket, air operated diaphragm pump, and interconnecting piping.

Table 6-18. Hydrocyclone Specifications (DD 963 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	13 gpm	2.5 x 1.3 x 5.25	3 x 2 x 7	17	132/150
Total (To achieve required processing capacity)	1	13 gpm	-	-	17	132/150

The hydrocyclone modules are designed for single-deck operation and would be installed in the current OWS room. The existing OWS would be removed and replaced with the hydrocyclone module.

6.5.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with hydrocyclones. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials required for operation and maintenance (e.g., oil and grease) are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While hydrocyclones require pressurized air to operate, observing standard shipboard safety procedures for handling compressed air systems should be adequate.

6.5.1.3 Mission Capabilities

The installation and operation of hydrocyclones on DD 963 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

6.5.1.4 Personnel Impact

The hydrocyclone unit runs in automatic mode, but still requires general supervision while the unit is operating. Based on an MPCD rated capacity of 13 gpm and the 485,000 gallons of bilgewater generated annually within 12 nm, the number of hours the hydrocyclone would be operated is 620 hours annually within 12 nm.

$$\frac{485{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{13\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 620\text{ hrs/yr}$$

The labor requirement for general oversight of the hydrocyclone was estimated to be 0.25 hours of general oversight for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, the annual labor requirement associated with the operation of a hydrocyclone within 12 nm is 78 hours.

$$\frac{620\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hrs labor}}{2\text{ hrs operation}} = 78\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 6.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm of shore is calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm of shore) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}850\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 2.7\text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of the hydrocyclone within 12 nm and transfer of waste oil generated within 12 nm on a DD 963 Class vessel is 80 hours.

The total labor requirement associated with vessel operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The volume of bilgewater generated beyond 12 nm (i.e., 1,830,000 gal) and resultant volume of waste oil that requires offloading to shore (i.e. 18,300 gal) are based on the DD 963 Class vessel underway bilgewater generation rate of 10,000 gpd. The underway generation rate is multiplied by the number of days spent beyond 12 nm (183 days). Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}830{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{13\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 2{,}300\text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2{,}300\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hrs labor}}{2\text{ hrs}} = 290\text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{18{,}300\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 10\text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of this vessel class beyond 12 nm is 300 hrs/yr.

Annually, the hydrocyclone requires approximately 1.5 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 hours of personnel hours of condition-based maintenance beyond 12 nm. Table 6-19 and Table 6-20 summarize the time-based and condition-based maintenance requirements, respectively for one hydrocyclone.

Table 6-19. Hydrocyclone Time-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and Inspect Strainer Basket	0.25	3 months	1
Inspect Air Diaphragm Pump for Wear	0.25	12 months	0.25
Replace Air Diaphragm	0.25	12 months	0.25
Total Annualized Hours	-	-	1.5

Table 6-20. Hydrocyclone Condition-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on operation hours within 12 nm)	Annualized Maintenance Hours (based on operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	-	0

Table 6-21 provides the annual labor hours required for operation and maintenance of the hydrocyclone.

Table 6-21. Hydrocyclone Annual Labor Hours (DD 963 Class)

	MPCD Option: Hydrocyclone
Operator Hours Within 12 nm	80
Operator Hours Beyond 12 nm	300
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	1.5
Total Time	390

Hydrocyclones do not have an impact on habitability. Hydrocyclones are closed systems, so no vapors are present. Manning requirements will be minimal because hydrocyclones require little maintenance, and operation can be fully automated. Periodic monitoring of the inlet and underflow pressures would be recommended to evaluate operating conditions and determine if maintenance is required.

6.5.1.5 Consumables, Repair Parts, and Tools

Consumables and repair parts, which should be on hand, include “O” rings and gaskets for the cyclone, a few spare cyclone liners, and some components (replacement diaphragm, etc.) for the pump. Consumables and repair parts do not significantly affect cost.

6.5.1.6 Interface Requirements

Table 6-22 summarizes the specific system interface requirements associated with the hydrocyclones.

Table 6-22. Hydrocyclone Interface Requirements (DD 963 Class)

Shipboard System	Hydrocyclone Interface Requirements
Compressed Air	65 psi, 18 scfm

DD 963 Class vessels are able to accommodate this interface requirement.

6.5.1.7 Control System Requirements

Hydrocyclones are generally designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. One level switch will start the unit(s) when the liquid level in the tank reaches a pre-set level. A second level switch signals the unit(s) to shut down when the liquid level in the OWHT drops to a pre-set level. Units have a flow sensor that will secure the system if the pump loses suction and a remote alarm/indicator panel, which would allow shipboard personnel to monitor the operating status of the units while in the automatic mode of operation.

6.5.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

6.5.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a hydrocyclone system on the DD 963 Class vessel.

6.5.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $7,600 (Lima, 2000). Based on previous AIT ship checks, the Navy estimates that installation of the hydrocyclone unit will cost $89,450 per vessel (Navy, 2000). To install the unit, the existing gravity coalescence unit must first be removed from the OWS room in order to make space available for the hydrocyclone system. The installation would require approximately three weeks to complete. The Navy estimates that the development of technical drawings will cost $25,120 ($1,136 per vessel) (Navy, 2000). Technical manuals cost approximately $85,000 ($3,867 per vessel) to develop a 150-page manual. The cost for training materials is approximately $9,330 ($424 per vessel) (Smith, 2001). The total initial cost of a hydrocyclone system on a DD 963 Class vessel is $102,500 per vessel.

6.5.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 82 personnel hours per year for operation, and time-based maintenance within 12 nm, as explained under Section 6.5.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the recurring labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{82\ \text{hrs}}{\text{yr}} = \$1{,}900\ /\text{yr inside } 12\ \text{nm}$$

Personnel Labor Beyond 12 nm

This MPCD requires 300 personnel hours per year for operation beyond 12 nm, as explained under Section 6.5.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{300\ \text{hrs}}{\text{yr}} = \$6{,}900/\text{yr outside } 12\ \text{nm}$$

The labor required to transfer waste oil generated by the hydrocyclone system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 6-23 summarizes the annual recurring costs of a hydrocyclone system on a DD 963 Class vessel.

Table 6-23. Annual Recurring Costs for Hydrocyclone (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	1.9
Beyond 12 nm	Navy	6.9

6.5.2.3 Total Ownership Cost (TOC)

Table 6-24 summarizes the TOC and annualized cost over a 15-year lifecycle of a hydrocyclone system on a DD 963 Class vessel.

Table 6-24. TOC for Hydrocyclone (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	102.5	102.5
Total Recurring	21	97
TOC (15-yr lifecycle)	123	200
Annualized	11	17

6.6 *IN SITU* BIOLOGICAL TREATMENT

In situ biological treatment of bilgewater is the addition of microbes to a vessel's bilge spaces to digest the oil content of the bilgewater. For *in situ* biological treatment to be effective, the microbes must be left in the bilge for a sufficient period of time to metabolize the bilgewater's oil content. According to the vendor, the most effective use of *in situ* biological treatment for the wastewater that accumulates in the bilge is to leave the *in situ* material in the bilge spaces on the vessel for a 30-day period to establish a population of microbes (Opsanick, 2000). Transferring bilgewater to shore or allowing additional bilgewater to be introduced to the bilge spaces before the 30-day period is complete may decrease the *in situ* biological treatment's effectiveness. Due to the lack of performance data, the extent to which the effectiveness of biological treatment would be decreased cannot be determined (Opsanick, 2000). However, the vessel would be continuously generating bilgewater during this period, disrupting the batch processing method recommended by the manufacturer. Further, the vessel’s total bilgewater generation over a 30-day period is at least 75,000 gallons. Leaving this volume of bilgewater in the bilge spaces to allow more complete treatment would inhibit the safe operation of vessels. Therefore, *in situ* biological treatment is not a feasible MPCD option group for vessels represented by DD 963 Class vessels.

6.7 OIL ABSORBING SOCKS (OASS)

OASs are designed to absorb oil floating on the surface of a body of water (Sorbent Products Inc., 2000). In this application, OASs would be placed inside the bilge areas of a DD 963 Class vessel to continuously absorb the waste oil from the bilgewater. When the OAS becomes fully saturated, they are manually removed, stored, and replaced with a new OAS. This use of OASs for DD 963 Class vessels poses concerns regarding the generation of solid waste, a potential to restrict emergency dewatering, and a potential fuel source that could contribute to the intensity of a fire involving the bilge spaces.

The use of OASs for DD 963 Class vessels will result in the generation of a large amount of solid waste. As noted earlier, DD 963 Class vessels generate approximately 25 gallons of waste oil per day while in port and 100 gpd while underway. The density of a saturated OAS is approximately 7.3 pounds per gallon of waste oil (Ergon Environmental Products Inc., 1998). OASs are solid media that trap and hold waste oil, a liquid. Therefore, using OASs would generate approximately 180 pounds of solid waste per day while in port. If used underway, OASs would generate approximately 730 pounds of solid waste per day. The removal of saturated OASs would require a high level of manual effort (i.e., labor provided by the ship's crew). The saturated OASs would need to be removed from the bilge and carried up from the lower decks of the vessel so they could be transferred to shore. By comparison, waste oil captured by the current MPCD option (i.e., the gravity coalescing OWS) remains a liquid waste stream and would only require a few minutes to pump the same amount ashore.

The presence of OASs in the bilge spaces would potentially restrict the flow of bilgewater through the normal and emergency dewatering pumps and strainers by clogging the suction points. The use of OASs in the bilge spaces of the majority of U.S. Coast Guard and Navy vessels would not be feasible due to vessel safety and survivability concerns. Both services prohibit (through practice) the presence of any loose materials or debris in the bilge areas that could potentially interfere with normal or emergency dewatering activities. Securing the OASs to a pipe or other type of fixture in the bilge is not feasible because the force of a shock or explosion would potentially dislodge the OAS. Furthermore, as the OAS absorbs oil it becomes a potential fuel source that could contribute to the intensity of an engine room fire involving the bilge spaces.

Based on the potential operational and safety impacts related to solid waste handling, emergency dewatering, and potential fire hazards, OASs are not a feasible MPCD option group for the DDG 51 Class vessel group.

6.8 FILTER MEDIA

The following sections discuss the feasibility and cost impacts of installing and operating a filter media secondary OWS unit on-board a DD 963 Class vessel.

6.8.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of filter media systems.

6.8.1.1 Space and Weight

One 10-gpm filter media polisher is proposed for this analysis. The polishing unit consists of oil absorbing filter media canisters and is designed to treat the OWS effluent before being discharged overboard. The 10-gpm filter media unit was selected as the secondary MPCD due to its ability to match the capacity requirements of the current MPCD and because the unit has been tested on Navy vessels. The polisher is comprised of three cylindrical tanks, installed in a triangular pattern, each containing three canisters filled with oil absorbing media. The unit would be installed in the upper level of Auxiliary Machinery Room No. 1, one level above the existing OWS unit. Installation of this MPCD requires the relocation of existing furniture (Navy, 2000). Table 6-25 summarizes the approximate space and weight of a 10-gpm unit.

Table 6-25. OWS Filter Media Polisher Specifications (DD 963 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	4 x 1.3 x 3.25	5.6 x 2.8 x 5.25	16.9	730/1675
Total (To achieve required processing capacity)	1	10 gpm	-	-	16.9	730/1675

6.8.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with this MPCD. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials required for operation and maintenance (e.g., oil and grease) are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material.

6.8.1.3 Mission Capabilities

The installation and operation of this MPCD on DD 963 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

6.8.1.4 Personnel Impact

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary units will not require significant additional oversight. Therefore, operator oversight hours associated with the secondary unit are assumed to be zero.

The recovered waste oil is absorbed into filter media canisters and the canisters must be offloaded. The time required to replace the filter media canisters is one hour for each unit. Because DD 963 Class vessels are equipped with one unit, the total time required to replace the filter media canisters is one hour. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a rated capacity of 10 gpm and a total of 480,000 gallons (equal to bilgewater generated annually within 12 nm minus 1 percent of oil removed by primary OWS) of effluent to be processed annually, the filter media will have to operate approximately 800 hours per year. Therefore, the filter media will have to be replaced every 6 months. The annual number of hours spent replacing the filter media canisters are 2.0 hours per year, as calculated below.

$$\frac{480{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{1\text{ hr labor}}{400\text{ hrs}} = 2.0\text{ hrs labor/yr}$$

Annually, the filter media canister requires 0 personnel hours of time-based maintenance, 2 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Condition-based maintenance beyond 12 nm is equal to zero because secondary MPCDs are only operated within 12 nm. Table 6-26 and Table 6-27 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one filter media canister.

Table 6-26. Filter Media Time-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
None	0	0	0
Total Annualized Hours	-	-	0

Table 6-27. Filter Media Condition-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 800 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Remove and Replace Filter Media Canister	1	400	2.0	N/A
Total Annualized Hours	-	-	2.0	N/A

Table 6-28 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

Table 6-28. Filter Media Annual Labor Hours (DD 963 Class)

	MPCD Option: Filter Media
Operator Hours Within 12 nm	0
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	2.0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	2.0

6.8.1.5 Consumables, Repair Parts, and Tools

The OWS filter media polishing unit requires the replacement of nine filter media canisters every six months. The canisters may be stored on the vessel or shoreside. No special repair parts or tools are required for the operation or maintenance of these units.

6.8.1.6 Interface Requirements

No specific system interface requirements are associated with the OWS filter media polishing unit.

6.8.1.7 Control System Requirements

The OWS filter media polishing system operates automatically in response to the primary OWS operation. Therefore, the polisher unit does not have any unique control system requirements.

6.8.1.8 Other/Unique Characteristics

The OWS filter media polishing systems were installed on two DDG 51 Class destroyers. However, these systems were removed because they failed to consistently produce an effluent with an oil content less than 15 parts per million (ppm) (Hopko, 1996). Navy ships with OWSs and Oil Content Monitors should attempt to limit oil and oily discharges to 15 ppm oil worldwide (Navy, 2002).

6.8.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a filter media system on a DD 963 Class vessel.

6.8.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $16,000 per vessel (Hanrahan, 1997). Based on previous ship checks by the AIT, the Navy estimates that the installation will cost $63,760 per vessel (Navy, 2000). The unit would be installed in the upper level of Auxiliary Machinery Room No. 1, one level above the existing OWS unit, and would require the relocation of existing furniture to make room for the new unit. The installation would require approximately two weeks to complete. Technical manuals cost approximately $85,000 ($3,867 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $13,520 ($615 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($424 per vessel) (Smith, 2001). The total initial cost of a filter media system on a DD 963 Class vessel is $85,000 per vessel.

6.8.2.2 Recurring Cost

The filter media unit requires 2 personnel hours per year for operation, and maintenance as explained under Section 6.8.1.4. The annual labor hours multiplied by the $22.64 per hour MPCD operator labor rate produces the recurring labor cost of $45/year.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{2.0\text{ hrs}}{\text{yr}} = \$45/\text{yr}$$

The replacement cost of filter media canisters is $7,300 per unit (Hanrahan, 1997). Because this vessel class requires one unit, the cost for canister consumables at each replacement interval is $7,300. The filter media canisters have to be replaced after approximately 400 hours of operation (Galecki, 2000). With a total rated capacity of 10 gpm and a total of 480,000 gallons of effluent to be processed annually, the filter media will have to operate 810 hours per year. Therefore, the filter media will have to be replaced approximately every 6 months, which results in an annual material cost of $15,000. The filter media canisters are combined and disposed of with the vessels' solid waste. Because of the relative infrequency and small volumes disposed, the Navy has not experienced any significant increase in their overall solid waste disposal cost.

The filter media canisters absorb the oil content of the oily bilgewater. Because the media canisters absorb the oil content, the filter media system does not produce waste oil that must be offloaded from the vessel via the waste oil tank. Table 6-29 summarizes the annual recurring costs for a filter media system used on a DD 963 Class vessel.

Table 6-29. Annual Recurring Costs for Filter Media (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	15
Beyond 12 nm	Navy	0

6.8.2.3 Total Ownership Cost (TOC)

Table 6-30 summarizes the TOC over a 15-year lifecycle for a filter media system on a DD 963 Class vessel.

Table 6-30. TOC for Filter Media (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	85	85
Total Recurring	160	160
TOC (15-yr lifecycle)	250	250
Annualized	21	21

6.9 MEMBRANE FILTRATION

The following sections discuss the feasibility and cost impacts of installing and operating a membrane filtration [ultrafiltration (UF)] secondary OWS unit on-board a DD 963 Class vessel.

6.9.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of membrane filtration secondary OWS.

6.9.1.1 Space and Weight

The 10-gpm UF membrane unit was selected as the secondary MPCD due to its ability to match capacity requirements of the current MPCD and because the unit was developed specifically for Navy vessels. The Navy expects this capacity to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is most critical. Once beyond 12 nm, the vessel will continue to operate its primary OWS and continue to operate in compliance with regulatory requirements. Table 6-31 summarizes the space and weight specifications of the 10-gpm unit.

Table 6-31. Membrane Filtration Specifications (DD 963 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	7x5x6.5	7 x 5 x 6.5	227.5	2700/3000
Total (To achieve required processing capacity)	1	10 gpm	-	-	227.5	2700/3000

The 10-gpm membrane unit would be installed in the upper level of Auxiliary Machinery Room No. 1. Relocation of existing furniture would be required to provide an installation envelope. The primary OWS unit is located on the lower level of the same space. UF membrane units are designed for single-deck operation. They can be provided to the installing activity fully assembled, or designed for easy disassembly into components small enough to fit through standard watertight doors. UF membrane systems will require minimal storage of additional spare parts (Price, 1999).

6.9.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with membrane systems. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While membrane systems require electrical power and operate under high pressure, observing standard shipboard safety procedures for handling electrical equipment and pressurized systems should be adequate. A Failure Mode, Effects and Criticality Analysis (FMECA) was generated for the UF system used on the USS CARNEY (DDG 64). The FMECA lists potential system failures according to their relative probability of occurrence, identifies safety hazards resulting from those failures, and recommends safety practices to reduce the associated safety risk. Applicable safety practices recommended by the FMECA will likely be implemented in conjunction with UF system installation on board DD 963 Class vessels.

6.9.1.3 Mission Capabilities

The installation and operation of membranes on DD 963 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

6.9.1.4 Personnel Impact

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary unit will not require significant additional oversight. Therefore, operator oversight hours associated with the secondary unit are assumed to be zero.

The waste oil removed from the bilgewater by the UF system must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 6.1.1.4. The labor hours associated with oversight of transfer of waste oil produced by a UF system on a DD 963 Class vessel are calculated by dividing the waste oil volume (1 percent of the membrane filtration system effluent volume) by the waste oil pump rate (10 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}800\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 24\text{ hrs labors/yr}$$

Annually, membrane filtration requires 9.3 personnel hours of time-based maintenance, 1.55 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Condition-based maintenance beyond 12 nm is assumed to be zero because secondary MPCDs will only be operated within 12 nm. Table 6-32 and Table 6-33 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a UF membrane system.

Table 6-32. UF Membrane Time-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and inspect permeate flow sensor	0.2	3 Months	0.8
Clean and inspect recirculation loop temperature sensor	0.2	3 Months	0.8
Clean and inspect continuous level transducer	0.2	6 Months	0.4
Clean and inspect high level sensor probe	0.2	6 Months	0.4
Calibrate pressure gauges	1.0	12 Months	1.0
Clean and inspect recirculation pump suction valve	1.8	12 Months	1.8
Clean membranes (no MRC; for scheduling only. Perform CLEAN cycle. Perform quarterly and when membrane resistance is greater than 100% as indicated on the control panel)	0.1	3 Months	0.4
Clean and inspect membrane system control panel	1.6	6 Months	3.2
Inspect membrane system grounding straps	0.1	12 Months	0.1
Perform lamp test of membrane system control panel; measure insulation resistance.	0.1	3 Months	0.4
Total Annualized Hours	-	-	9.3

Table 6-33. UF Membrane Condition-Based Maintenance (DD 963 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 8 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Clean and inspect duplex strainer baskets	0.1	As required*	0.1	0
Replace membranes (accomplished shoreside)	-	As required*	-	0
Drain membrane system	0.5	As required*	0.5	0
Fill membrane system with water	0.05	As required*	0.05	0
Replace feed pump mechanical seal. Inspect internal parts	0.3	As required*	0.3	0
Replace recirculation pump mechanical seal. Inspect internal parts	0.6	As required*	0.6	0
Total Annualized Hours	-	-	1.55	0

**For calculations it was assumed that the time-based maintenance was performed annually.*

Table 6-34 provides the annual labor hours required to operate and maintain the UF membrane system on a DD 963 Class vessel.

Table 6-34. UF Membrane Annual Labor Hours (DD 963 Class)

	MPCD Option: Filter Media
Operator Hours Within 12 nm	24
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	1.55
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	9.3
Total Time	35

6.9.1.5 Consumables, Repair Parts, and Tools

On vessels equipped with the UF system, membranes are scheduled to be replaced after approximately 2400 hours of use. At this time, new, clean sets of membranes are put in the UF system and the old, used ones are sent to shore to be cleaned. This regular maintenance does not require any consumables, as the membranes are exchanged. Furthermore, no special tools are required to operate or maintain the units.

6.9.1.6 Interface Requirements

The UF system interface requirements are summarized in Table 6-35. These requirements are not expected to have a substantial impact on DD 963 Class vessels.

Table 6-35. UF Membrane Interface Requirements (DD 963 Class)

Shipboard System	Interface Requirement (10-gpm system)
Electric Power	440 Volts/3 Phase/ 60Hz
Compressed Air	80 to 100 psi, 5 scfm (operate valve actuators)
Potable Water	Fresh water back flush of membranes, 10 gpm @ 30 psi
Drainage	Concentrate from recirculation sub-system drains to WOT. When back flushing membranes, oily waste flushed from system is diverted to OWHT.

DD963 Class vessels are able to support these requirements.

6.9.1.7 Control System Requirements

The UF system operates automatically in response to the primary OWS system. Therefore, the UF system does not have any unique control system requirements.

6.9.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

6.9.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a UF membrane system on a DD 963 Class vessel.

6.9.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $200,000 per vessel (Smith, 1999). Based on previous ship checks, the Navy estimates that installation of the UF unit will cost $92,250 per vessel (Navy, 2000). The membrane unit would be installed in the upper level of Auxiliary Machinery Room No. 1, and relocation of existing furniture would be required to provide an installation envelope. The installation would require approximately three weeks to complete. Technical manuals cost approximately $85,000 ($3,867 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $21,250 ($966 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($424 per vessel) (Smith, 2001). The total initial cost of a UF system on a DD 963 Class vessel is $300,000 per vessel.

6.9.2.2 Recurring Cost

The UF membrane system requires 35 personnel hours per year for operation, condition-based maintenance, and time-based maintenance, as explained under Section 6.9.1.4. The annual labor hours multiplied by the $22.64 per hour MPCD operator labor rate produces the first operating year recurring labor cost of $790.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{35\,\text{hrs}}{\text{yr}} = \$790/\text{yr}$$

The labor required to transfer waste oil generated by the membrane filtration system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 6-36 provides the annual recurring costs for a UF membrane system on a DD 963 Class vessel.

Table 6-36. Annual Recurring Costs for UF Membrane System (DD 963 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	0.79
Beyond 12 nm	Navy	0

6.9.2.3 Total Ownership Cost (TOC)

Table 6-37 summarizes the TOC and annualized cost over a 15-year lifecycle for a UF membrane system on a DD 963 Class vessel.

Table 6-37. TOC for UF Membrane System (DD 963 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	300	300
Total Recurring	8.8	8.8
TOC (15-yr lifecycle)	310	310
Annualized	26	26